APPLICATION OF LOWER PUNCH VIBRATION TO IMPROVE THE MECHANICAL STABILITY OF TABLETS

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ABSTRACT

A sufficient mechanical stability of tablets to be compacted prevents problems during tableting (e.g. sticking, capping, lamination) and is crucial with regard to further processing steps such as coating or packaging. Often, an improvement of the mechanical stability is only achievable by an adaption of the production settings (die disk speed) or an alteration of the powder blend composition. In the present study, a novel lower punch vibration device was developed and implemented on a rotary tablet press to improve the mechanical stability of the resulting tablets without changing the production conditions or the powder formulation. Various types of microcrystalline cellulose with different physical properties were selected. The powders were investigated concerning their powder flow, density, particle morphology and surface area and the tablets concerning their weight, tensile strength, and capping index. The results showed that externally applied lower punch vibration improved the mechanical stability of the investigated tablets beyond the adaption of the production settingss and the physical properties of the powder blend.

Keywords: Tableting, lower punch vibration, mechanical stability, lamination.

INTRODUCTION

The mechanical stability of a tablet is an important attribute and affects further handling steps of the tablet such as coating, packaging, and the end use by the patient. An insufficient mechanical stability of tablets is often caused by tablet failures such as capping or lamination. Capping describes the detachment of the top or bottom part of the tablet, whereas lamination is characterized by horizontal micro cracks [Mazel, 2015]. The reasons for the occurrence of these phenomena are complex and depend on the powder blend properties (deformation properties, relative density, compressibility) and/or the process settings (rotor speed, compaction force, tooling). In the past, only few solution approaches were introduced to reduce the capping or lamination tendency and to improve the mechanical stability of the tablet without changing the process conditions or altering the composition of the powder blend [Levina, 202]. A new promising approach to reduce or prevent tablet failures might be the application of externally lower punch vibration. Preliminary studies revealed that lower punch vibration during the die filling step enables the densification of the powder bed within the die leading to a different particle arrangement [Kalies, 2019]. Thus, the aim of the present study was to investigate in more detail the effect of external lower punch vibration under production conditions with regard to the mechanical stability of the resulting tablets.

RESEARCH CONCEPT

Materials

Microcrystalline cellulose (Parmcel 102, Parmentier, Germany; MC-12, Blanver, Brasilia; Vivapur® 200, JRS Pharma, Germany; Avicel® 301, FMC, USA), magnesium stearate (Lehmann & Voss, Germany).

Methods

Powder Characterization

According to the Ph. Eur., the bulk and tapped-density (jolting volumeter, Stav 2003, J. Engelsmann, Germany), the true density (helium pycnometer; AccuPyc 330; Micrometrics, Germany) and the relative density (bulk density / true density) were determined. The powder flow was characterized by the Hausner ratio, the compressibility index, and by ring shear cell measurements (RST-XS, Dr. Dietmar Schulze Schüttgutmesstechnik, Germany). Hence, the powder flow function (FFC) was examined at a mean consolidation stress of 5.0 kPa and calculated as follows:

$$\mathrm{FFC} = \frac{\text{Consolidation stress}}{\text{Unconfined yield strength}} \tag{1}$$

In addition, the particle shapes were visualized with a scanning electron microscope (LEO 1525, Carl Zeiss, Germany) and the particle size distributions were determined with a laser diffractometer (Helios, Sympatec, Germany).

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Tablet Characterization

The investigated tablets were analyzed with a multifunctional hardness tester (TBH 525; Erweka, Heusenstamm, Germany) with regard to their weight, thickness and crushing strength. Afterwards, the tensile strength (Eq. 2), and capping index (Eq. 3) were calculated.

$$\sigma = \frac{2 \cdot F}{\pi \cdot d \cdot t} \qquad (2)$$

where F is the crushing force (N), d the tablet diameter (mm), and t the tablet thickness (mm).

$$\text{Capping Index} = \frac{(5 \cdot N_{op} + N_h)}{N_t} \qquad (3)$$

where N_{op} is the number of capped/laminated tablets after tableting, N_h the number of capped/laminated tablets during hardness testing, and N_t the total number of investigated tablets.

Tableting

Tableting was performed in single punch mode on a Fette 102i rotary tablet press with 10 mm flat faced punches. An automatically rotating filling wheel was used as filling unit. Before tableting, 0.5 % (w/w) of magnesium stearate was added to the powder blends which were mixed for 3 min. The target tablet weight was approximately 300 mg for each powder blend. The vibration equipment, described by Kalies et al. [Kalies, 2018], was composed of a modified filling cam and an externally mounted pneumatic turbine vibrator (MTT 13; Mooser, Germany).

RESULTS

The determined physical powder properties are listed in Table 1.

Table 1: Physical properties of the investigated MCC types.

MCC Type	FFC	Hausner ratio	Relative density (g/cm^3)	Particle size d_{50} (µm)
MCC 102	3.90	1.33	0.208	98.23
MCC 12	12.93	1.35	0.275	150.51
MCC 200	4.95	1.31	0.366	213.78
MCC 301	4.01	1.23	0.291	58.44

The resulting tensile strengths of the tablets manufactured conventionally and by application of lower punch vibration are displayed in Fig. 1A and B, respectively. Obviously, the tensile strength decreased distinctly at higher rotor speeds (Fig. 1A).

Application of externally lower punch vibration led to comparatively less pronounced decrease of the tensile strength (Fig. 1B) and it was possible to manufacture tablets with a sufficient tensile strength, even at high rotor speeds. The resulting tensile strengths of the tablets were obviously directly linked to the physical properties of the respective powder blends.

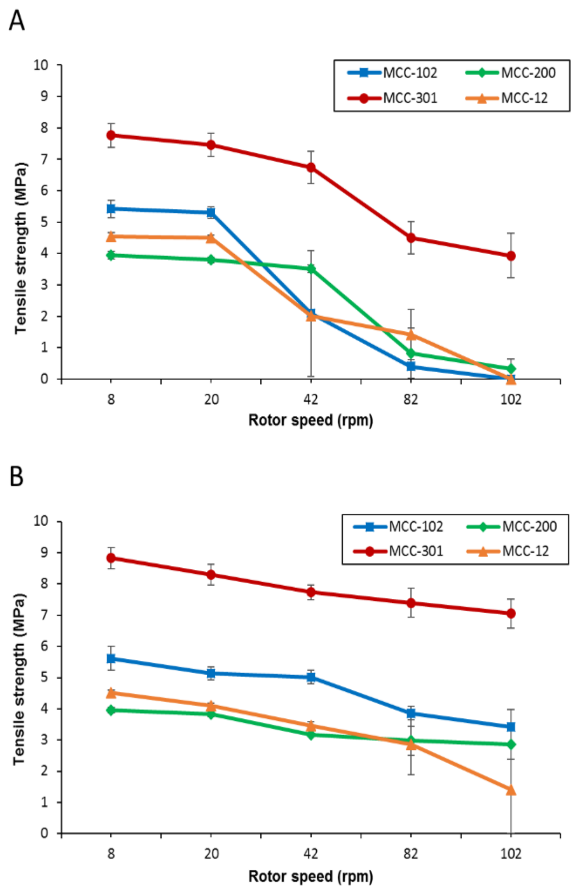

Fig. 1: Tensile strength of the investigated MCC tablet formulations depending on the applied rotor speed after conventional tableting (A) and by application of lower punch vibration (B) (means ± SD, n = 40).

The capping indices of the investigated MCC formulations are displayed in Fig 2. The results of the MCC-301 tablets are not shown, because no lamination occurred. In accordance with the results shown in Fig. 1A, the capping indices increased at higher rotor speeds during conventional tableting. In comparison, lower punch vibration was able to decrease the capping index and thus the lamination tendency to a significant extent even at high rotor speeds.

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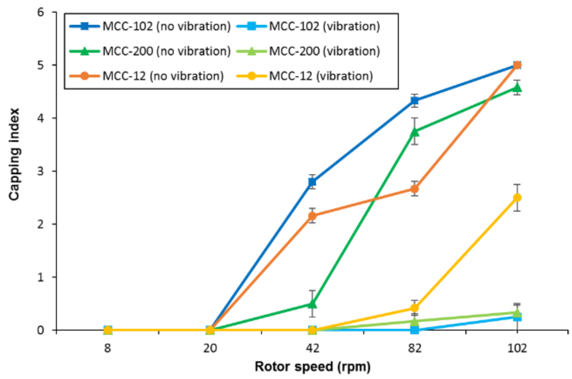

Fig. 2: Capping indices of the investigated MCC formulations depending on the applied rotor speed and the externally applied lower punch vibration (means ± SD, n = 20).

DISCUSSION

As shown in Fig. 1A, it was possible to manufacture tablets with sufficient tensile strength even at high rotor speeds by application of lower punch vibration. The applied lower punch vibration probably led to an enhanced die filling resulting in a more homogeneously and denser powder bed packing within the die. As a consequence of this "pre-densification" during the die filling process and prior to the main compaction step, the number of potential binding points and interparticle interactions between the particles increased, which ultimately led to an improved mechanical stability of the tablets. The lamination tendency was also distinctly decreased by the application of lower punch vibration (Fig. 2). This observation is attributed to the densification step of the powder bed within the die and the associated improved removal of entrapped air. The volume of entrapped air particularly depends on the physical powder properties and on the production settings (rotor speed). A low relative density in combination with a broad particle size distribution and needle shaped particles may increase the volume of entrapped air. Hence, a powder blend such as MCC-301 with a nearly spherical particle shape, a narrow particle distribution, a high relative density, and an adequate powder flow, showed a higher tensile strength and a less pronounced lamination tendency in comparison to MCC-102, MCC-12, and MCC-200. Furthermore, the removal of entrapped air is limited by the adjusted rotor speed.

CONCLUSIONS

In the present study, it was shown that the tensile strength as well as the lamination tendency of the tablets prepared from the investigated powder blends definitely depended on the physical properties of each powder blend. Moreover, the rotor speed and thus the resulting time for filling and compression strongly affected the mechanical stability of the prepared tablets. It is assumed that the application of external lower punch vibration during the die filling step and prior to the main compaction step leads to a pronounced increase of the tensile strength as well as a decrease of the capping index in comparison to conventional tableting. This is attributed to the removal of entrapped air and a rearrangement of the particles within the powder bed inside the die. Thus, external lower punch vibration might be a promising approach to improve the mechanical stability of tablets and to reduce or prevent capping or lamination during or after tablet manufacturing

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